3 Petabytes or Bust:

Observation Planning for NISAR

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NISAR Background

- Concept: Advance Deformation, Ecosystem and Ice sciences with global scale Synthetic Aperture Radar (SAR) time-series data
  - Spaceborne L-band and S-band SAR instruments
  - Data collection rates from up to 5 Gbps
  - Averaging ~25 Tb/day collected, downlinked data
    - Over a minimum three year science mission duration ~= 3 Petabytes of radar data
  - 12 day repeat cycle for Interferometric SAR

CLASP Background

- CLASP is the software tool for scheduling and planning science observations on NISAR
  - Generically it generates remote-sensing observations schedules for
    - One or more slewing spacecraft and/or multiple sensors, satisfying…
    - multiple observation campaigns over multiple areas of interest and ranges of time
- In use since 2009, used for several missions' studies

NISAR
NASA - ISRO SAR Mission

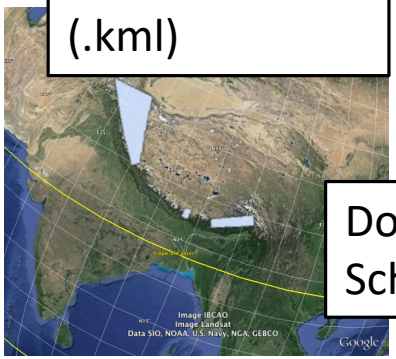
CLASP Modeling

- Resource Usage Modeling
  - Schedules observations within model of resources and constraints of the spacecraft
    - E.g. instrument data rate -> solid-state-recorder volume usage
    - E.g. system power usage -> battery state of charge
  - Designed to be adapted per mission
- Has strong geographic/geometric functionality
  - Integrated with NAIF SPICE toolkit
    - Library of software shared across NASA: An observation geometry system for planetary science missions
  - Can evaluate geographic target coverage using grid points for speed, or polygonal shards for accuracy

Typical CLASP: workflow

Spacecraft Definition and Orbit

Target Definitions (.kml)

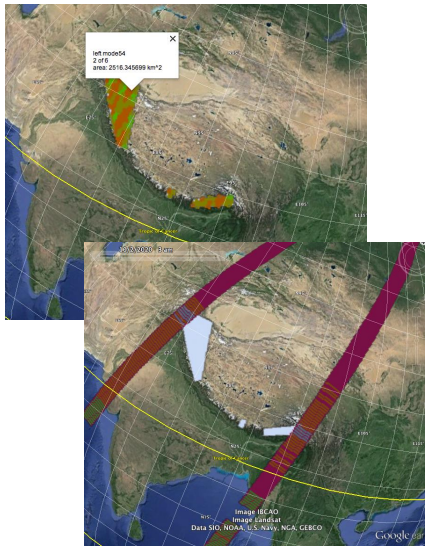


Downlink Schedule

(Optional) Previous Observation Schedule

Scheduler

Optimization Iterations

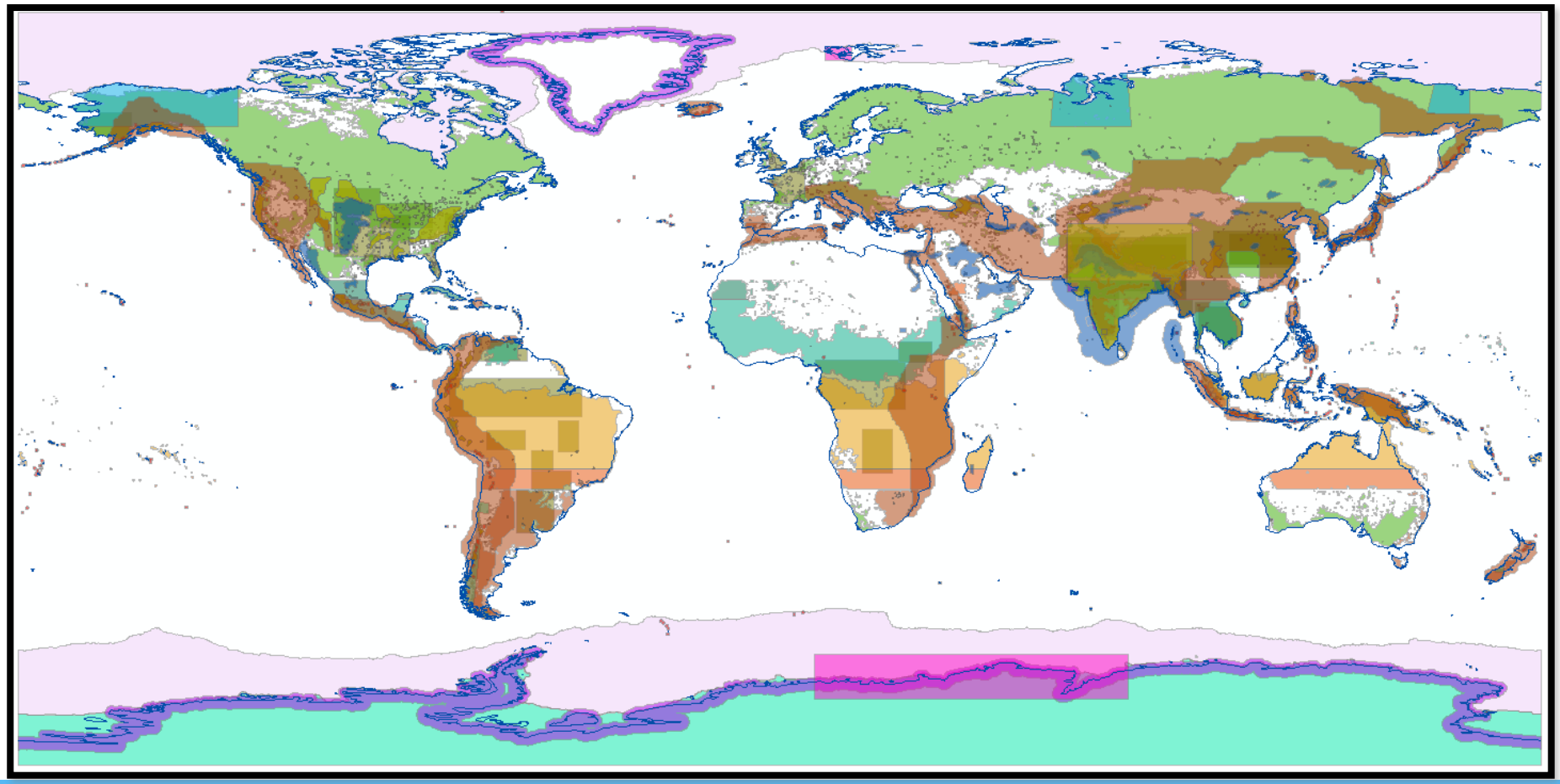


Observation and Activity Schedule

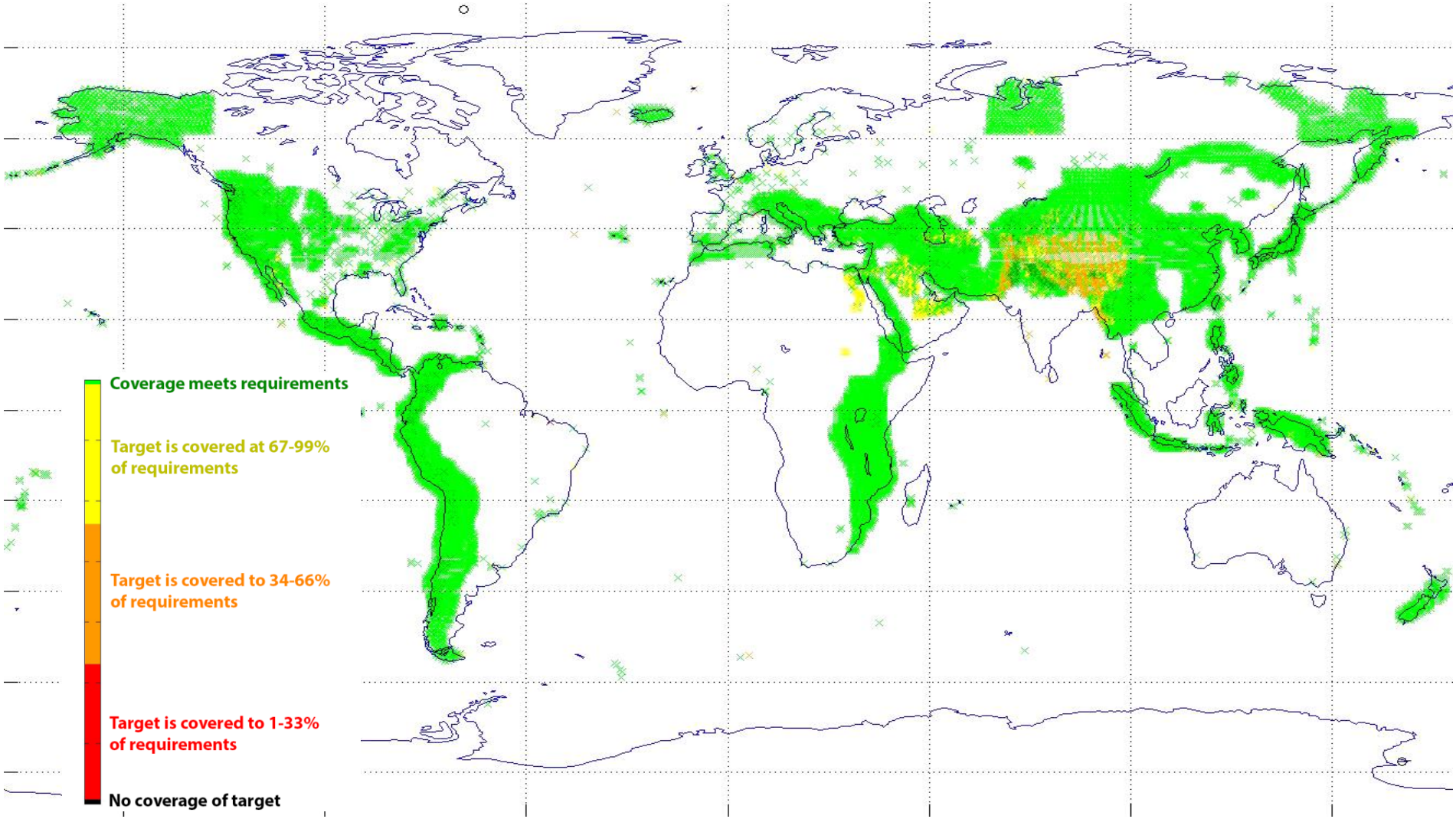
External changes to scheduling problem, e.g. new campaign requirements, campaigns over longer durations, urgent response activities inserted/dropped, or campaign target filters altered

NISAR Pre MCR Planning

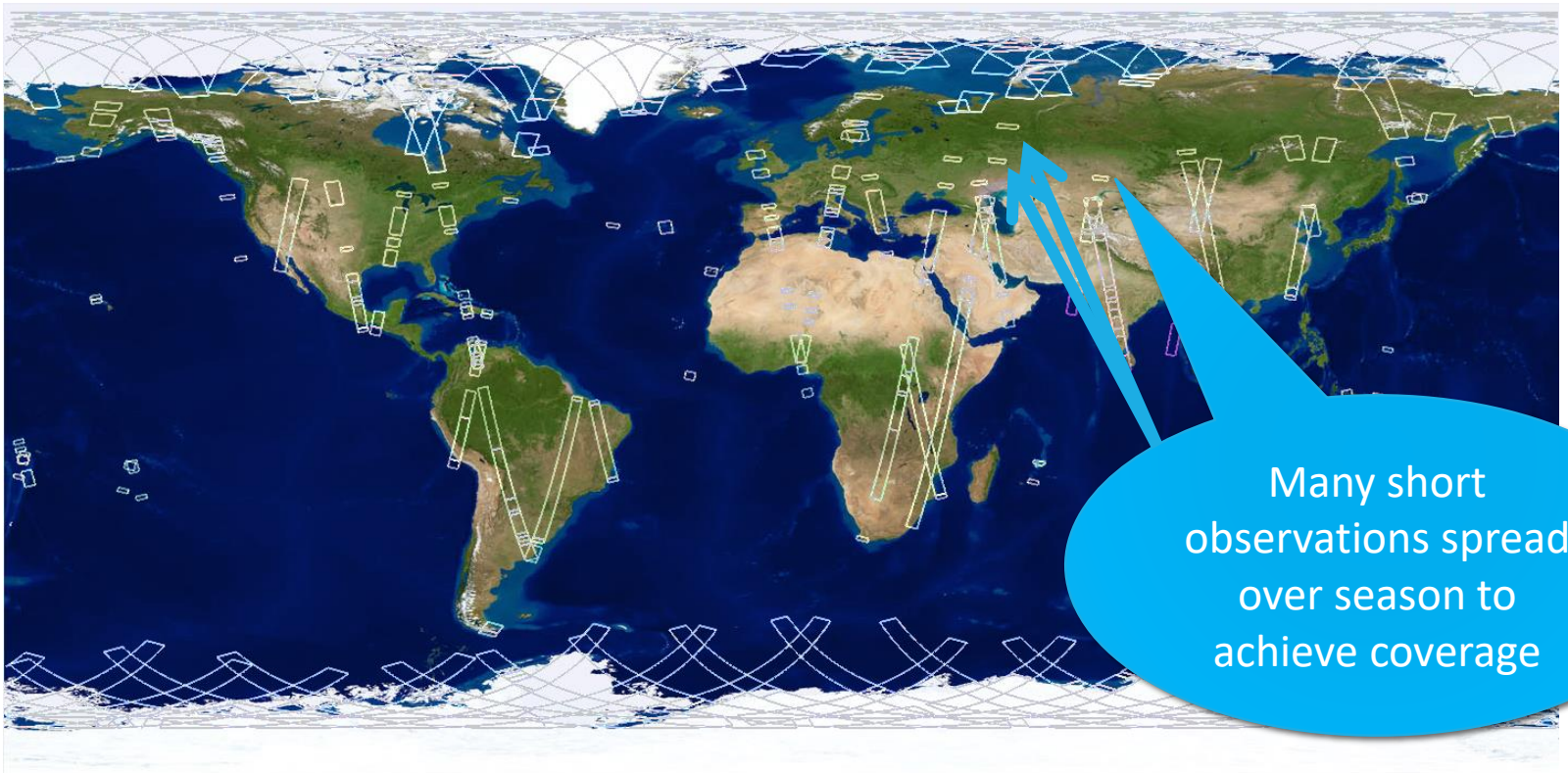
- Seven 12 day cycles, 84 day simulation durations (1 season)
- 25 unique science targets and 10 radar modes
- Coverage optimized by CLASP

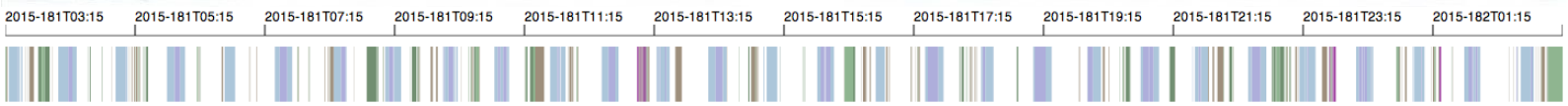


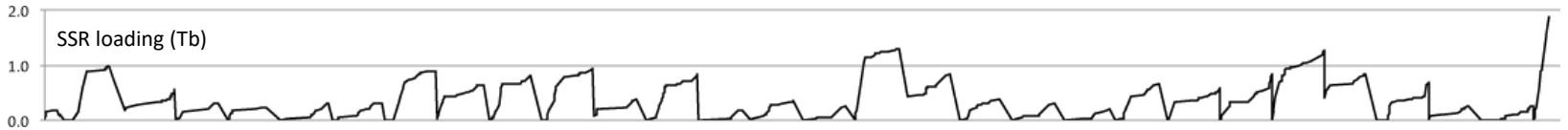
MCR: L-Band Deformation Coverage



MCR Science Plan– Sample Day

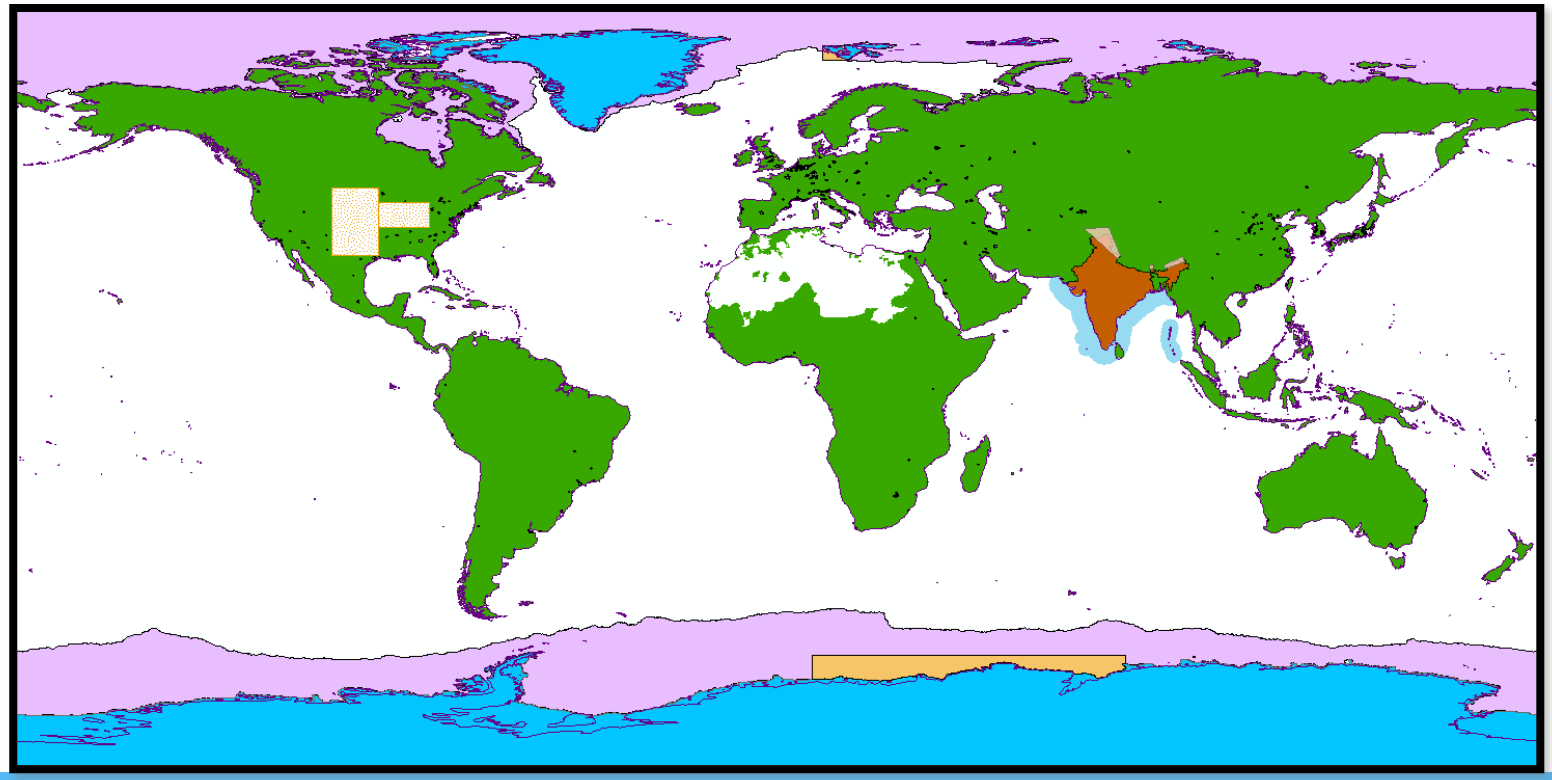




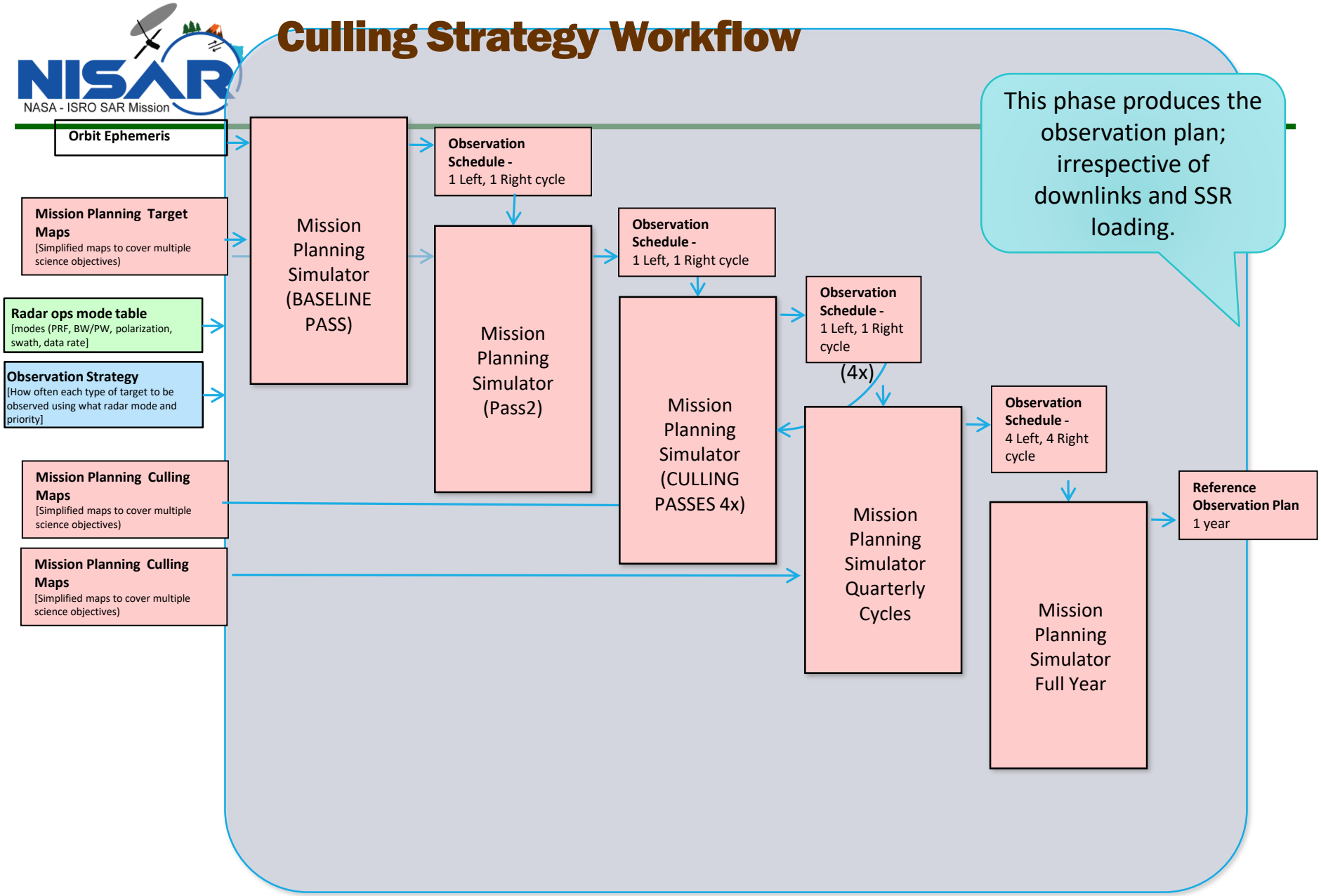


NISAR Post-MCR Planning

- CLASP used without optimization routine/iterations
- Simulate several 12 day cycle templates to repeat over time
- Science target masks and radar mode sets reduced and designed to be compatible
- Systematically filter (cull) some observations at high latitudes to avoid excessive coverage and reduce data-volume



Culling Strategy Workflow



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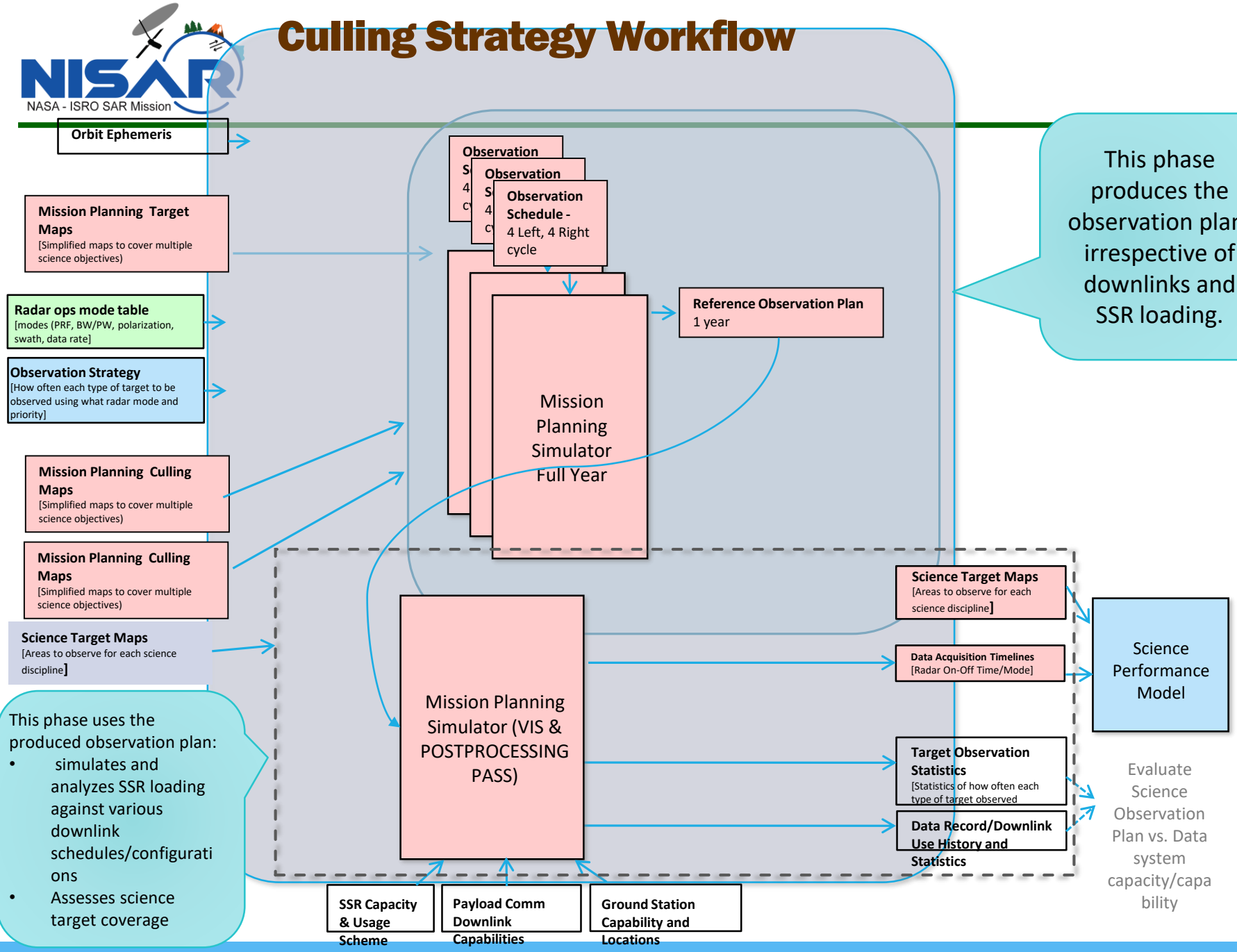


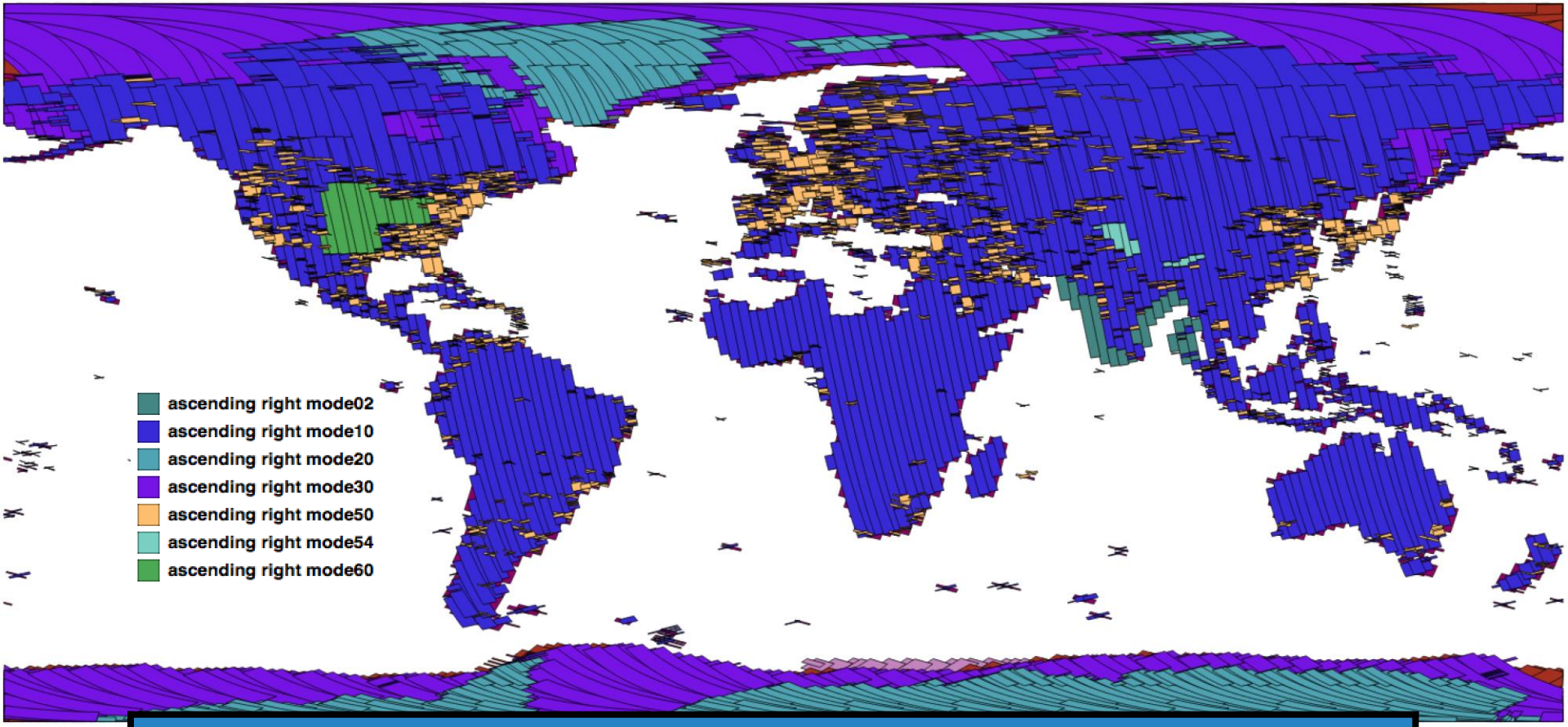
Modes/Culling Approach

Target	Mode	Data Rate (Mbps)	Culling Approach
Land Serves both Ecosystems and Solid-Earth, & Volcanoes	20+5 MHz DP (mode10)	942.39	Every day: Take everything in equatorial band Even day: Observe *in double coverage bands* Every 3 days: Observe area between *triple coverage latitude* towards each pole
Land Ice	80 MHz SP, half swath (mode20)	765.69	Every day: Take everything in equatorial band Odd day: Observe in *double coverage bands* Every 3 days: Observe area *between triple coverage latitude* towards each pole
Sea Ice	5 MHz SP (mode30)	96.07	No culling. Target areas vary seasonally
Urban/Anthro	40+5 MHz DP (mode50)	1718.41	No culling.
Agriculture	40+5 MHz QP (mode60)	3346.63	No culling.

Modes/Culling Approach

ISRO Targets			
ISRO Ag	L: 40+5 MHz QP S: 25 MHz CP (mode63)	4991.73	Take only descending
ISRO Ocean Applications	S: 10 MHz DP (mode02)	513.36	Take only ascending
ISRO Sea Ice	L: 20+5 MHz DP S: 25 MHz CP (mode43)	2188.84	Take only descending, every 3 days
ISRO Land Ice	L: 40+5 MHz DP S: 37.5 MHz CP (mode54)	3630.77	No culling

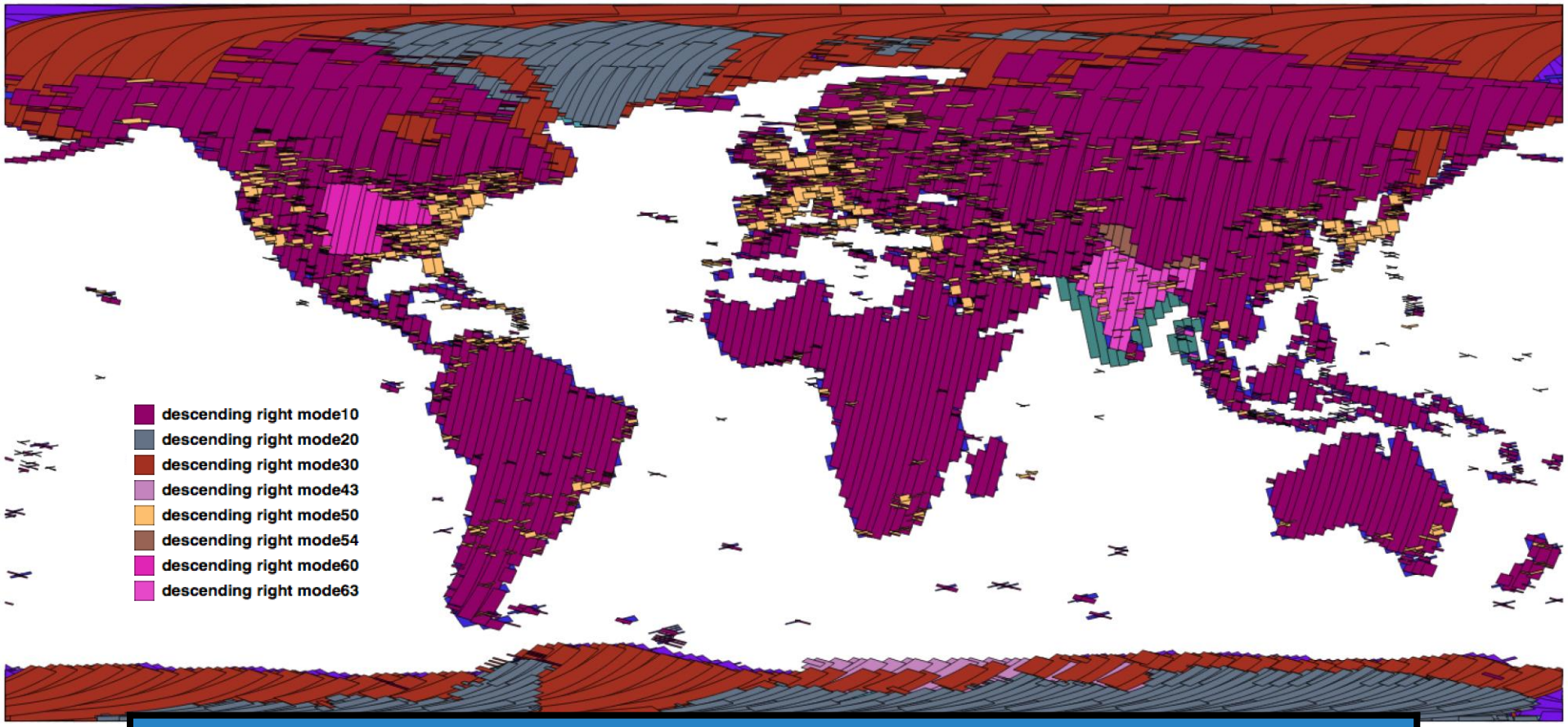
NISAR Culling Concept



Zone (right looking)	Background Land	Zone (right looking)	Land Ice
57° to 69° N	Every even day in cycle	73.7° to 79° N	Every odd day in cycle
69° to 90° N	Every third day in cycle	79° N to 90° N	Every third day in cycle+1

- Different culling latitudes in South. Latitudes swap N/S when left looking.

NISAR Culling Concept



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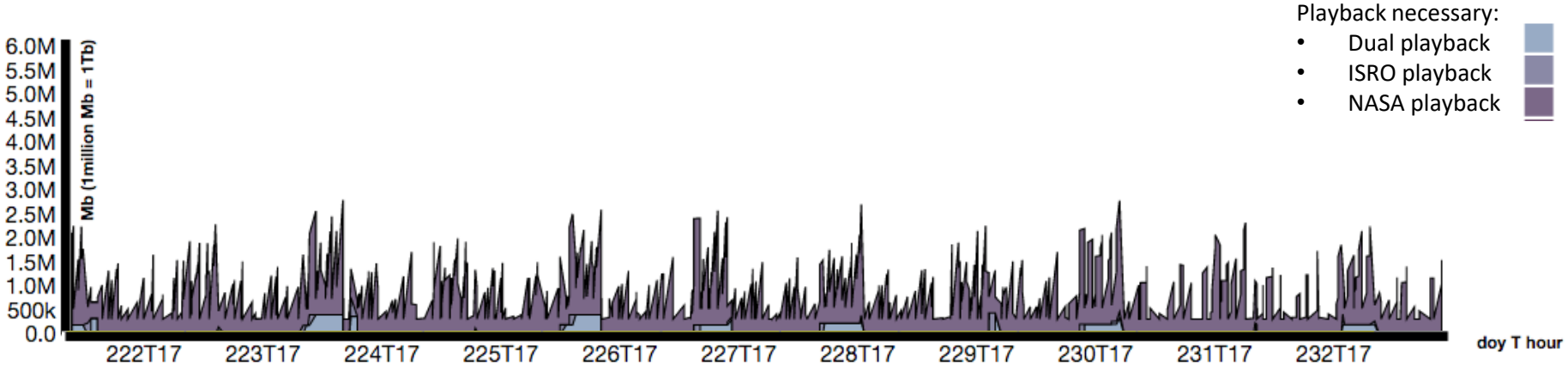
CLASP Adaptation

- Core modeling resources of CLASP can be extended for particular mission designs
  - Extend/detail the constraints in the optimization loop, or in a post-processing step
- For NISAR CLASP adapted a range of SSR models for trade studies
  - Size, physical/logical partitioning schemes
  - Data file playback state
  - Downlink schemes/schedules

SSR Modeling Example

- Stacked area plot of loading of a hypothetical design point SSR
  - With the above constructed observation plan, and data-volume production
  - A hypothetical, monolithic, 6Tb SSR
    - Volumes are broken out by file-downlink status
  - This plot represents an optimistic schedule of downlinks
    - Monte-carlo simulations of downlink schedules will characterize our sensitivity of this or other designs to variations in availability of downlink tracks, and drive our agreement with the Near Earth Network and flight operation rules



NOTE: for illustration only. Not representative of current baseline

NISAR Usage of CLASP
Tactical and Operations

- As mission design proceeds
  - Science Definition Team may relax or add new campaigns
  - Or Downlink, or onboard storage capabilities, or other constraints might change
  - Engineering activities inserted/altered
  - CLASP will be used to generate a new reference plan for the remainder of mission and provide
    - Coverage analysis
    - Time ordered listing of observations

NISAR Usage of CLASP Tactical and Operations

- CLASP will serve as helper software to other tools to tactically mature the reference mission into the Coordinated Observation Plan
  - Downlink schedule altered from idealized to short-term projection of contacts
  - Future portion of reference plan taken “off the shelf”
    - 1-3 week portions
  - History of execution and observations actually acquired also input to CLASP
  - CLASP optimizes to potentially “reacquire” missed observations within available margin

Conclusion

- CLASP has adapted to several mission planning strategies and design points
- To deliver a reference observation plan to meet NISAR science objectives
- NISAR will continue to evolve
  - to assist in generating operational commands
  - and more accurately model constraints as the system design matures.

NISAR
NASA - ISRO SAR Mission

Backup slides

Input: Science Targets

- Regions of Interest described in a Keyhole Markup Language (KML) file / compatible with popular tools (e.g. Google Earth).
- Embedded text specifies science campaign scheduling priority and weight, spacecraft geometric constraints, required (minimum) sensor modes, time range and frequency of interest.

Input: Sensor Definition

- Sensors are defined by a text file or embedded in a KML file
- Every sensor has defined:
  - A trajectory of the spacecraft platform
  - Its availability over time
  - Its slewing capacity and/or left and right looking modes, and swath-size (angular)
  - Sensor modes, their data-rates, and their inter-compatibility (or “hierarchy”)

NISAR
NASA - ISRO SAR Mission

CLASP Scheduling

- Schedule optimization
  - It can optimize through iterations
  - Greedy scheduler attempts to satisfy targets on a first opportunity basis via user-provided prioritization, orbit/radar swath geometry, target areas, and compatibility between defined sensor modes
  - This Squeaky Wheel Optimizer iterates greedy scheduler with increased priority on previously missed science targets
  - Other optimization algorithms can be added in the adaptation

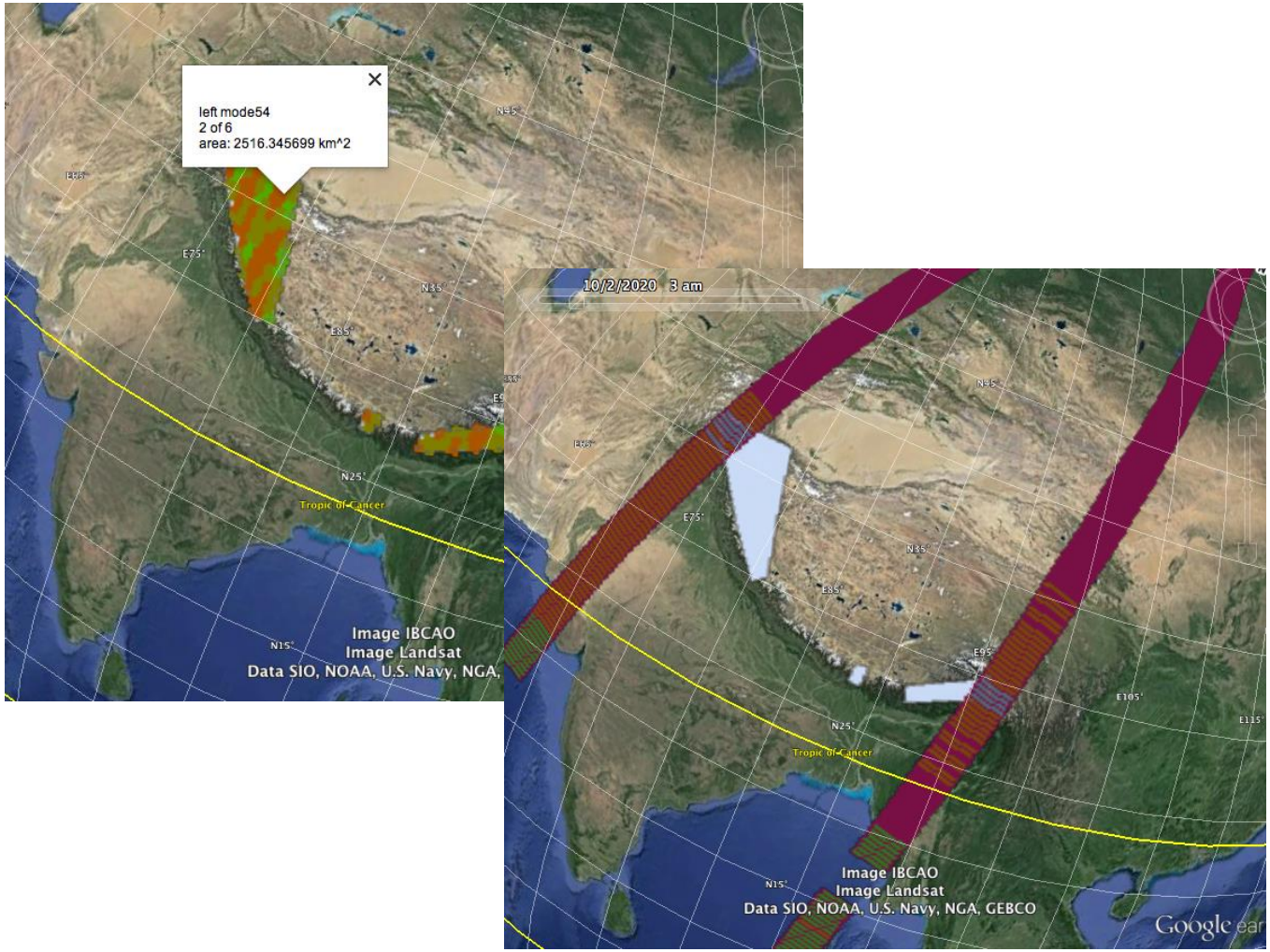
Input/Output: Timelines

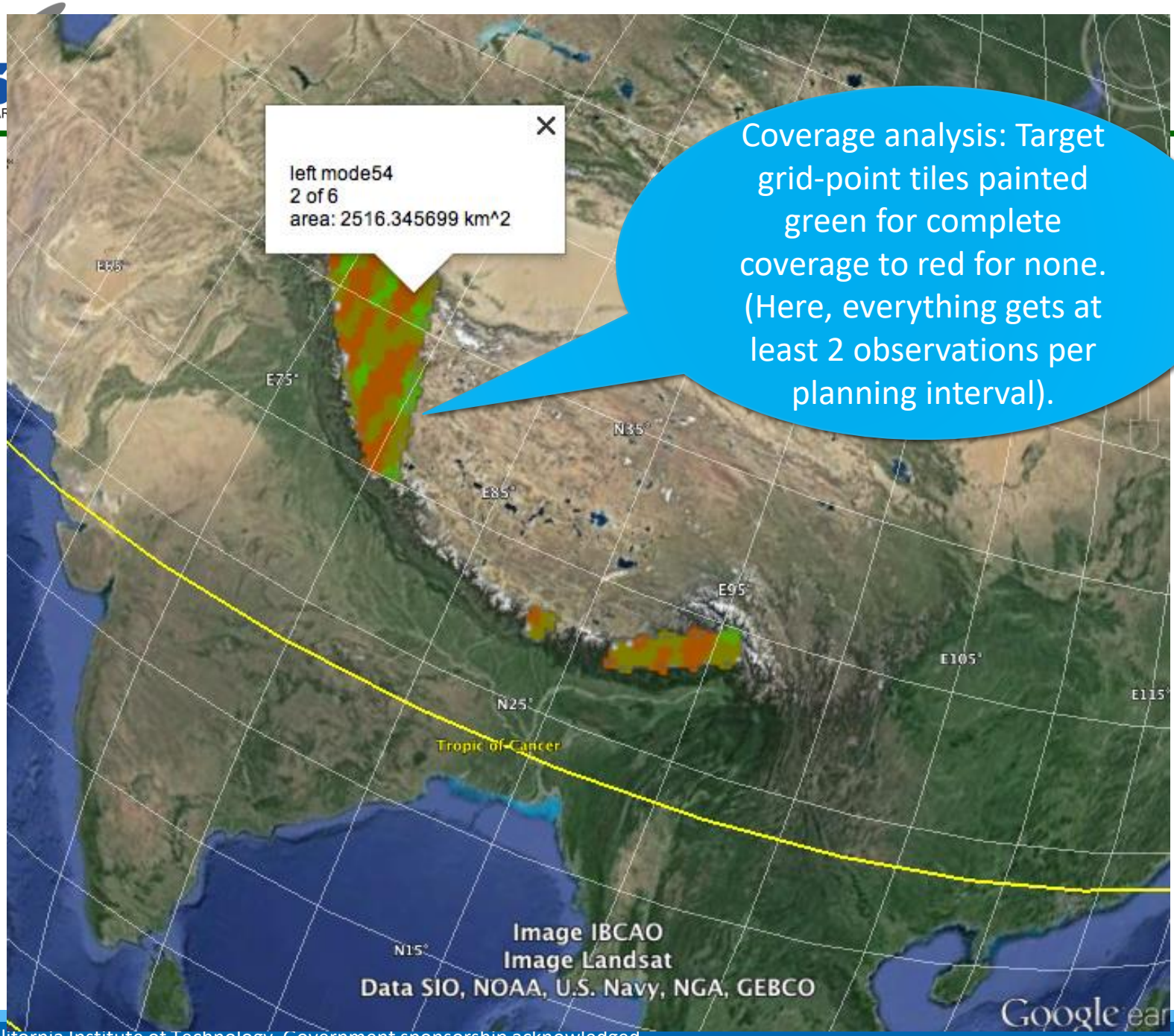
- CLASP outputs a file of a sequence of activities
  - Typically instrument observation start/end times
- CLASP can receive as input the same file format (E.g., downlink timeline)
- Text file
  - Time-stamped instrument modes and durations
  - Downlinks of specific rates
  - One line per activity

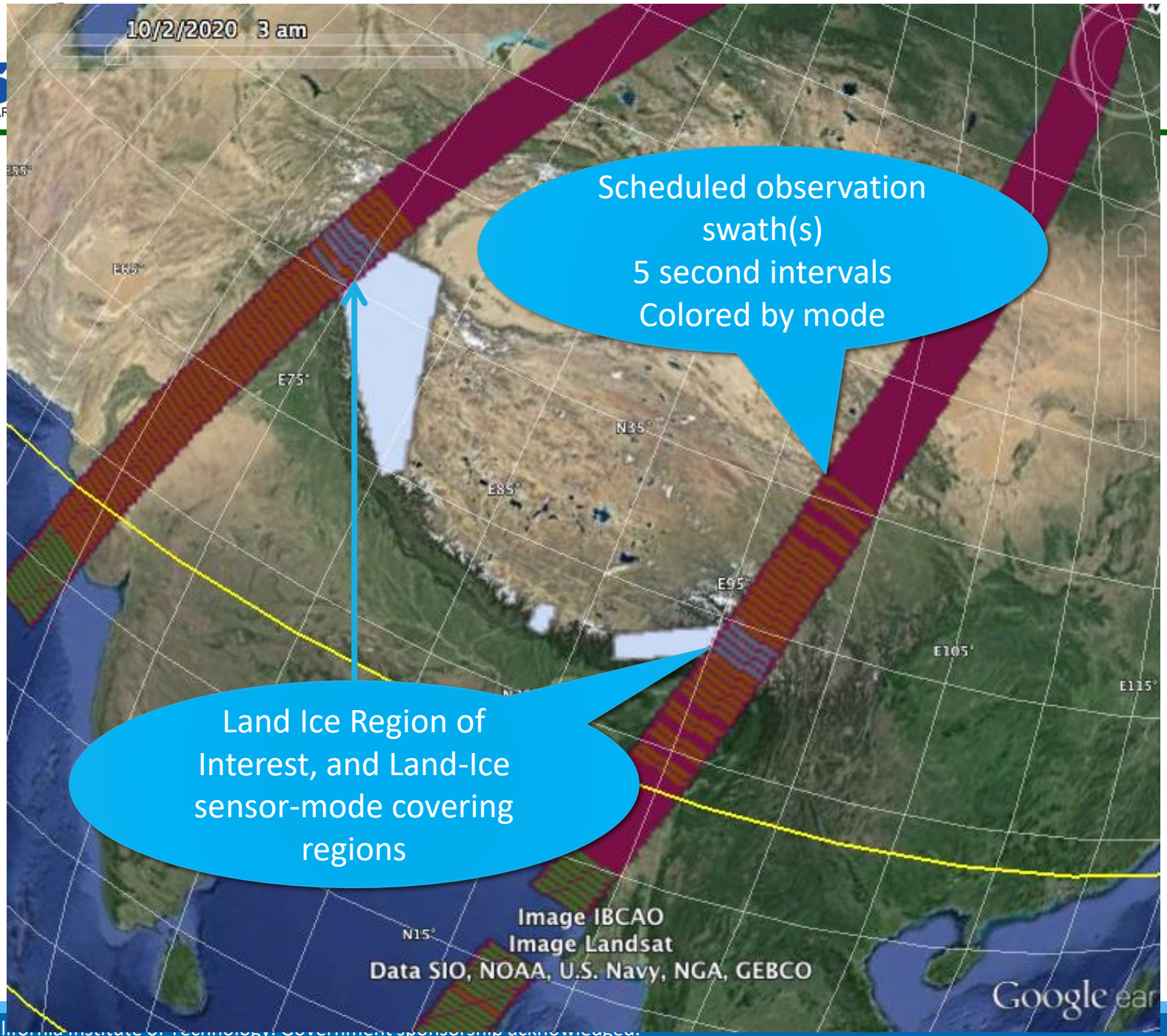
Interface: Visual Aids

Visual aids

- KML files to load in Google Earth or similar tool to visualize observations over time and space, and coverage analysis of targets



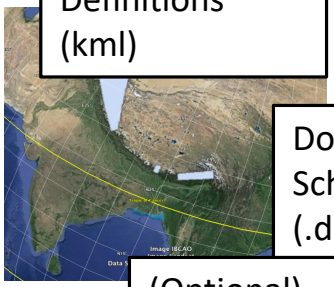




CLASP: reference plan updates

Spacecraft Definition and Orbit (kml+bsp)

Target Definitions (kml)



Downlink Schedule (.dat file)

(Optional) Previous Schedule (.dat file)

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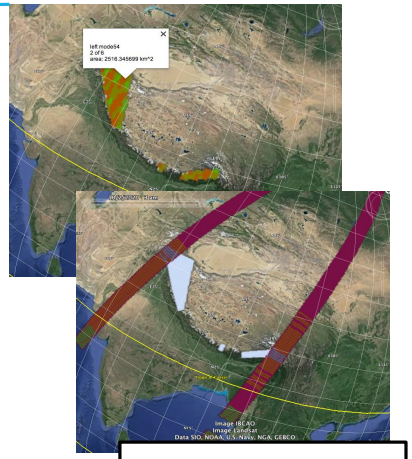

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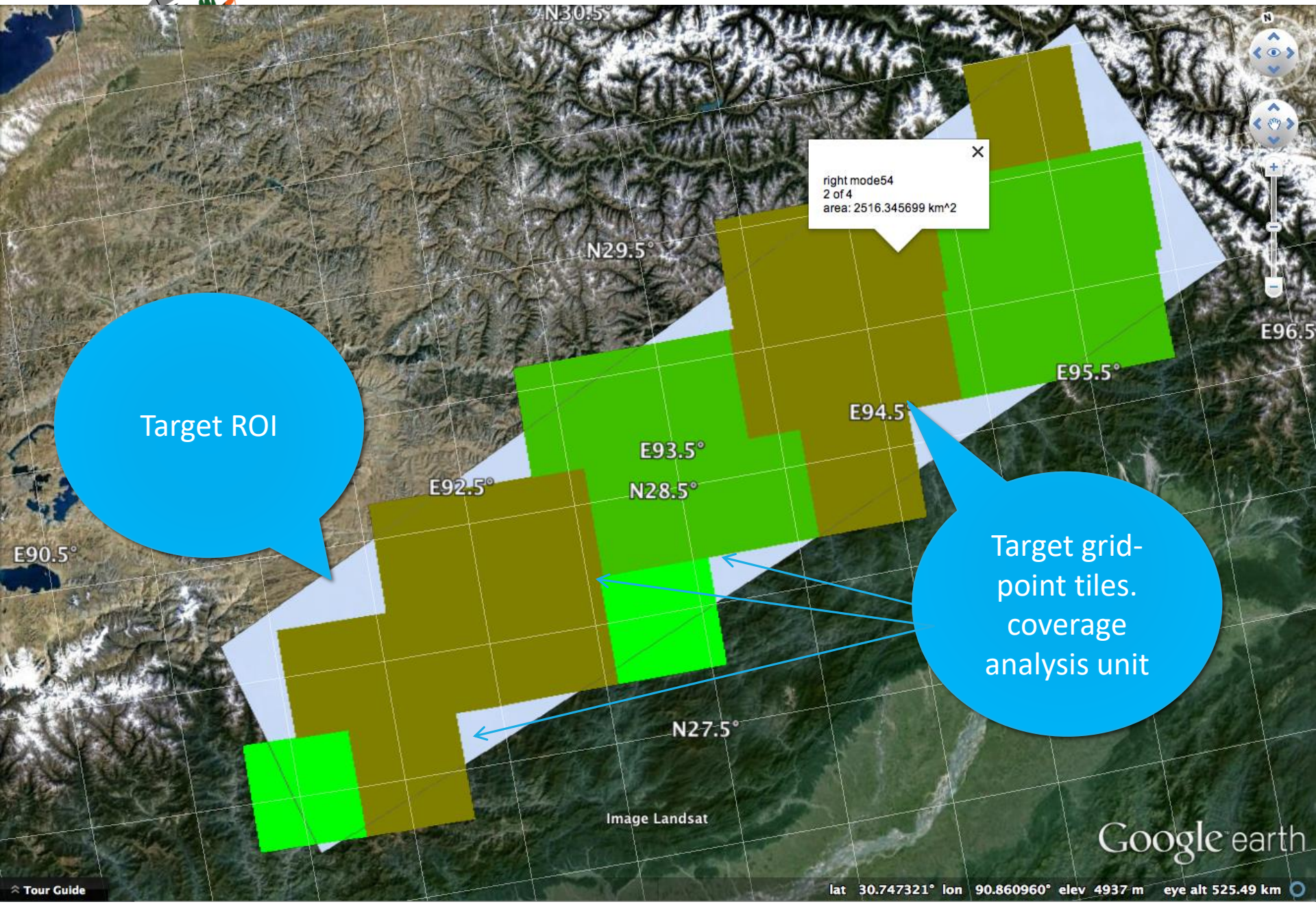
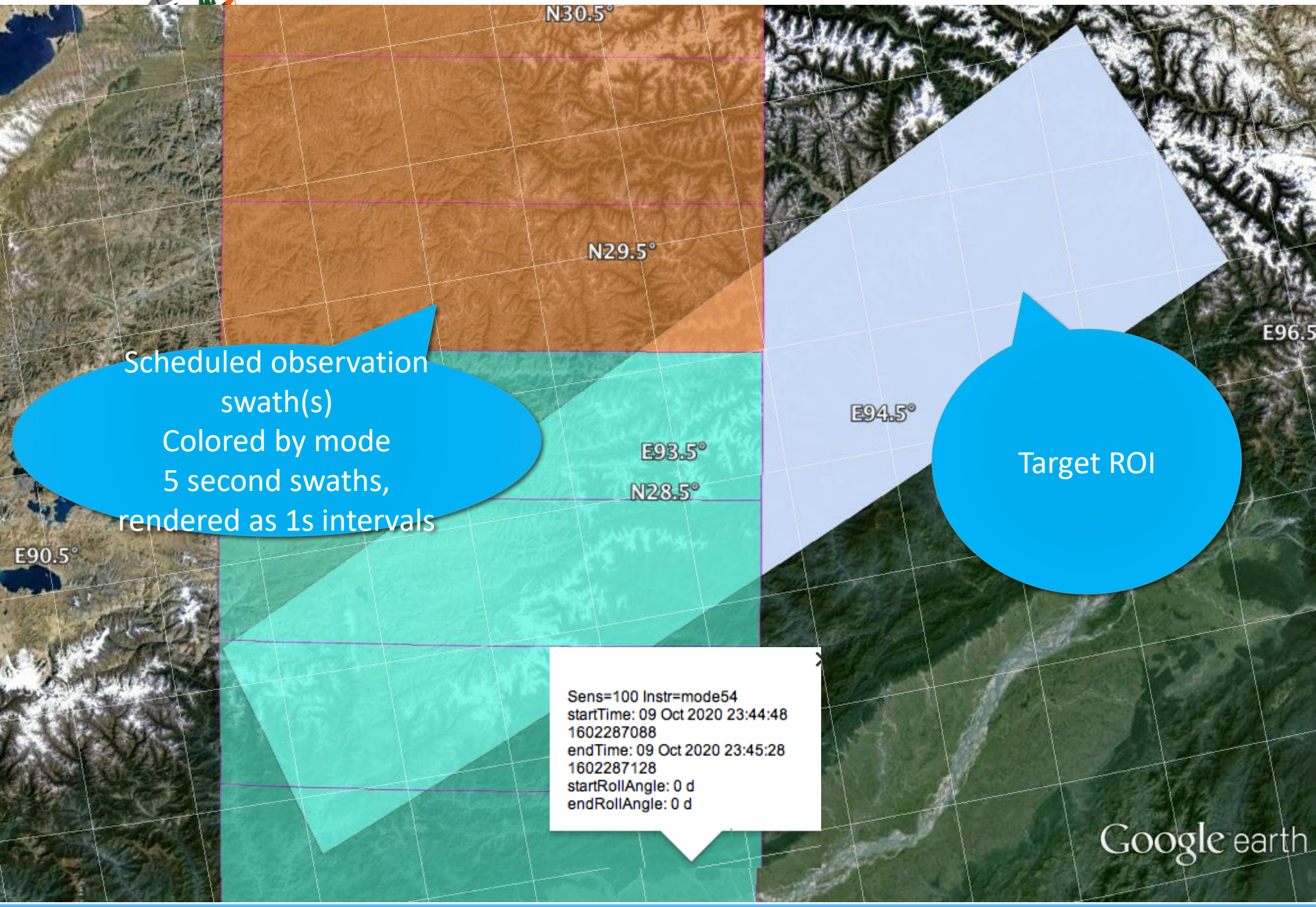
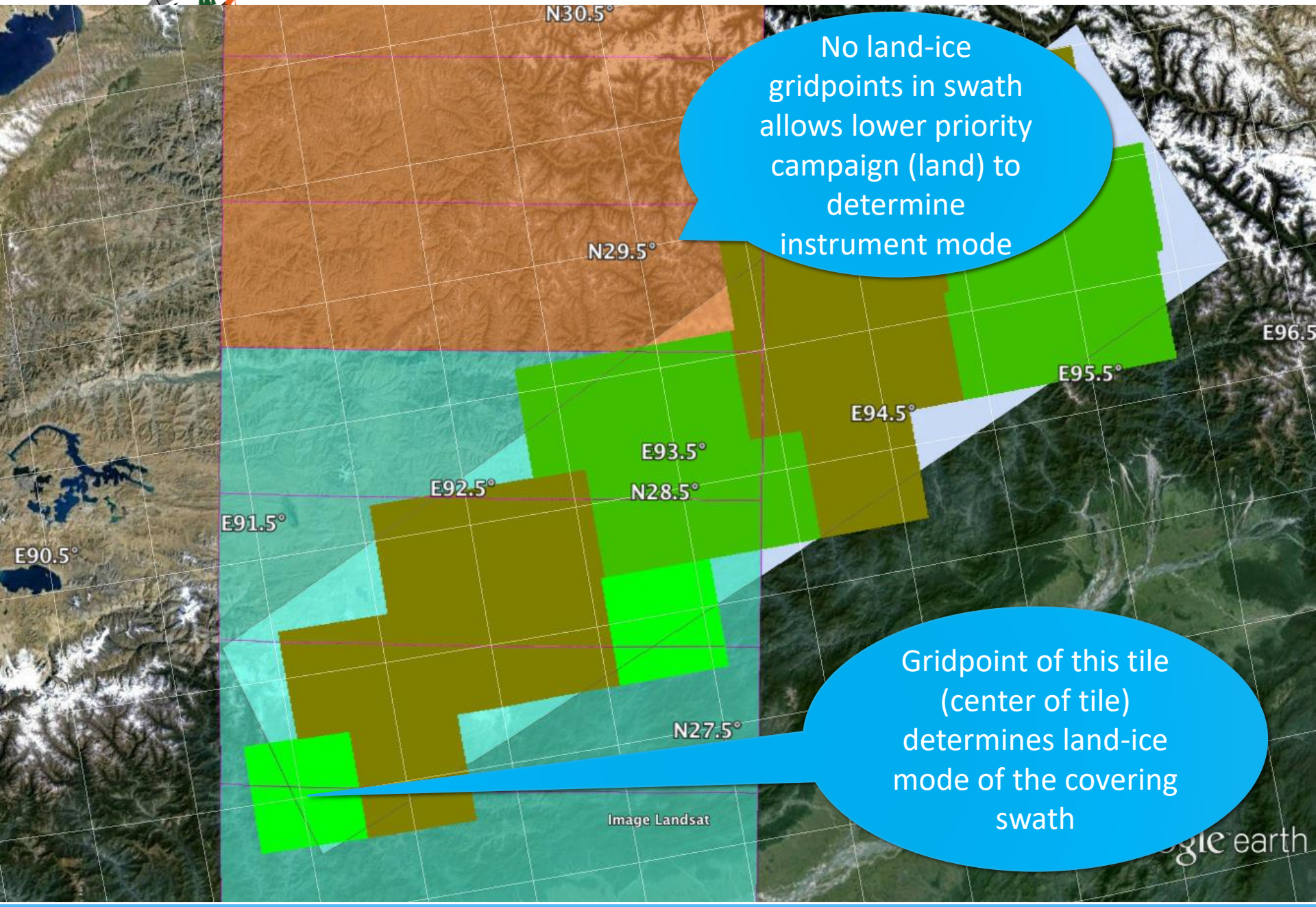
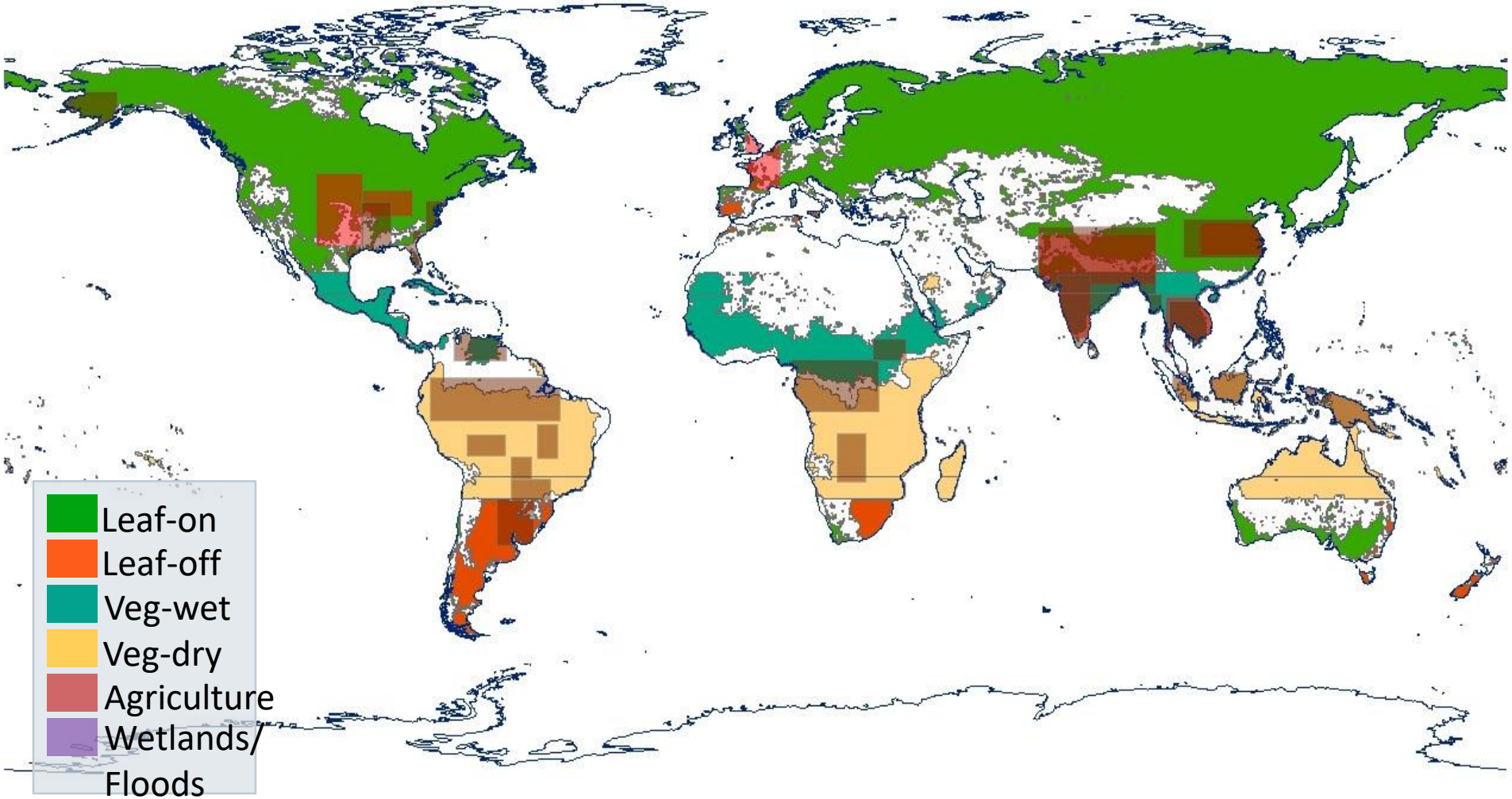


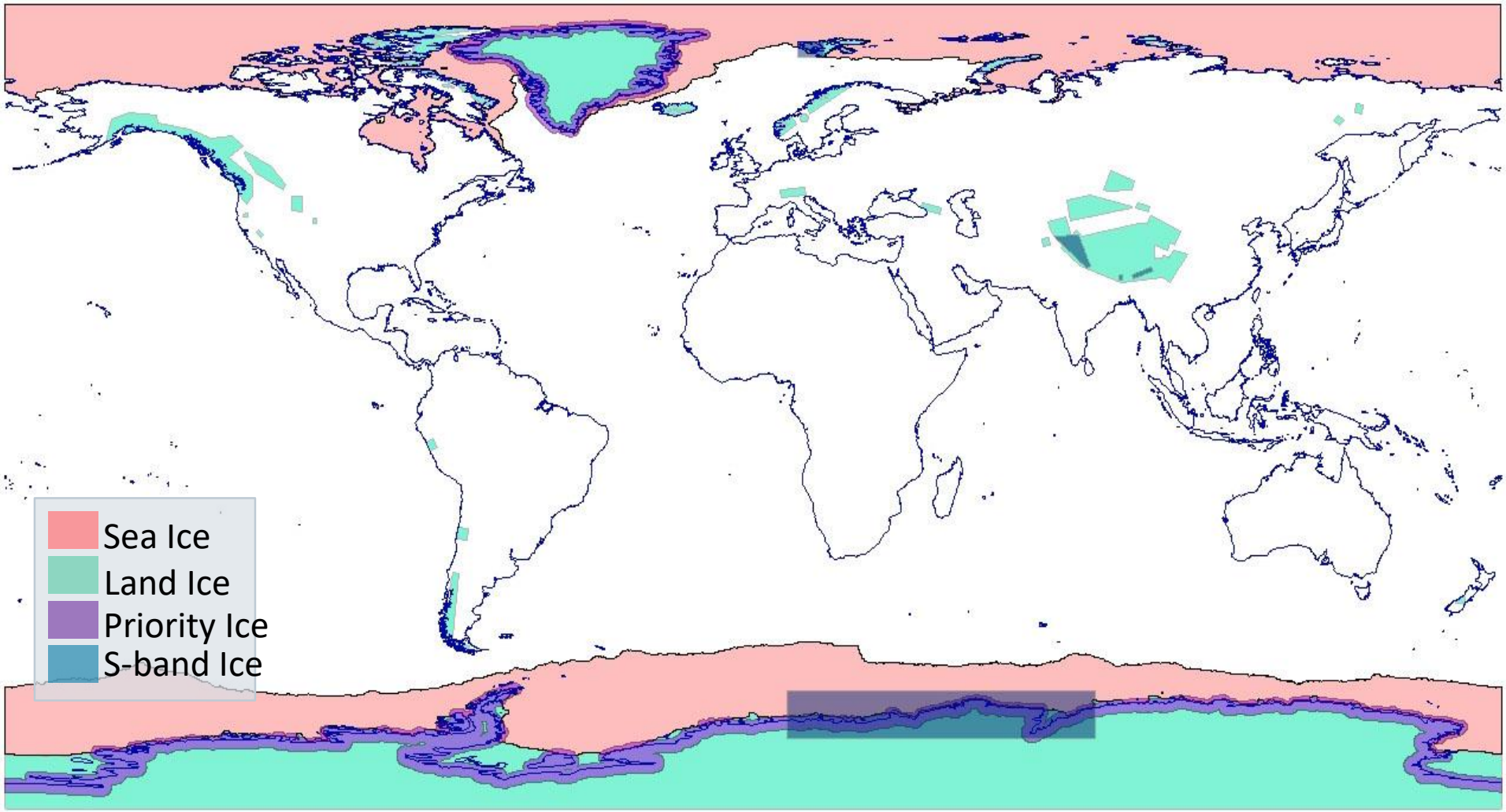




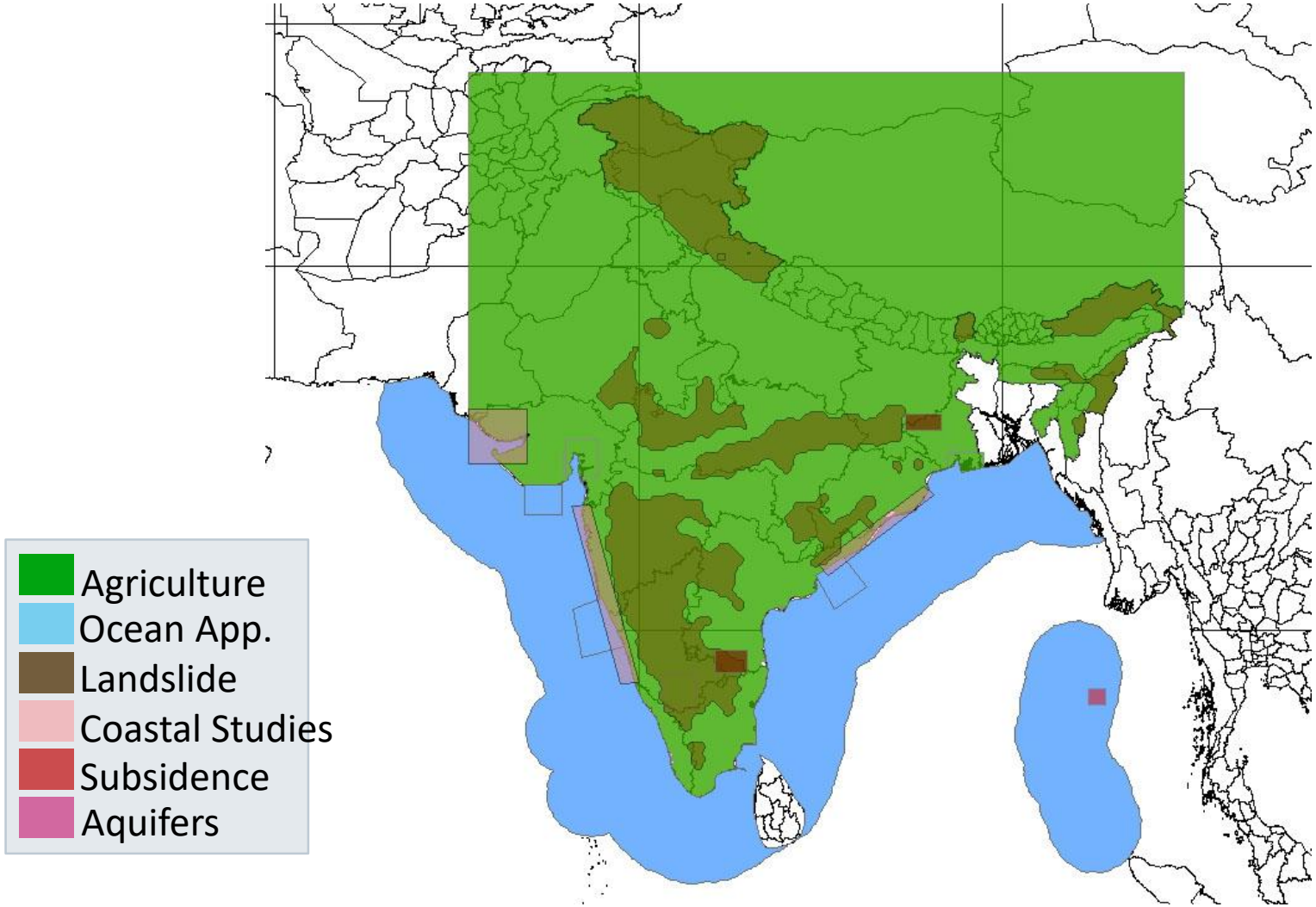
MCR L-Band Targets: Vegetation



MCR L- and S-Band Targets: Ice



MCR S-Band Non-Ice Targets



Mission Planning Simulator

- Simulate science data acquisition (with radar mode) timeline per science observation prescription and associated data generation, recording, downlink profile per radar, SSR, downlink capabilities/capacity
  - Use science prescribed observation target type, regions, and frequency, with radar modes and orbital data, to simulate radar on-off timeline of observation coverage
  - Use simulated data acquisition timeline and radar mode, with simulated on-board data storage (SSR) read-write scheme and capacity and ground downlink TTC station locations, to simulate data generation (write) and downlink (read) against SSR capacity and downlink capacities